Ocean Sciences 2004
OS52-C

Nearshore Processes and Sediment Dynamics Generated by a Frontal Passage: West Ship Island, Mississippi

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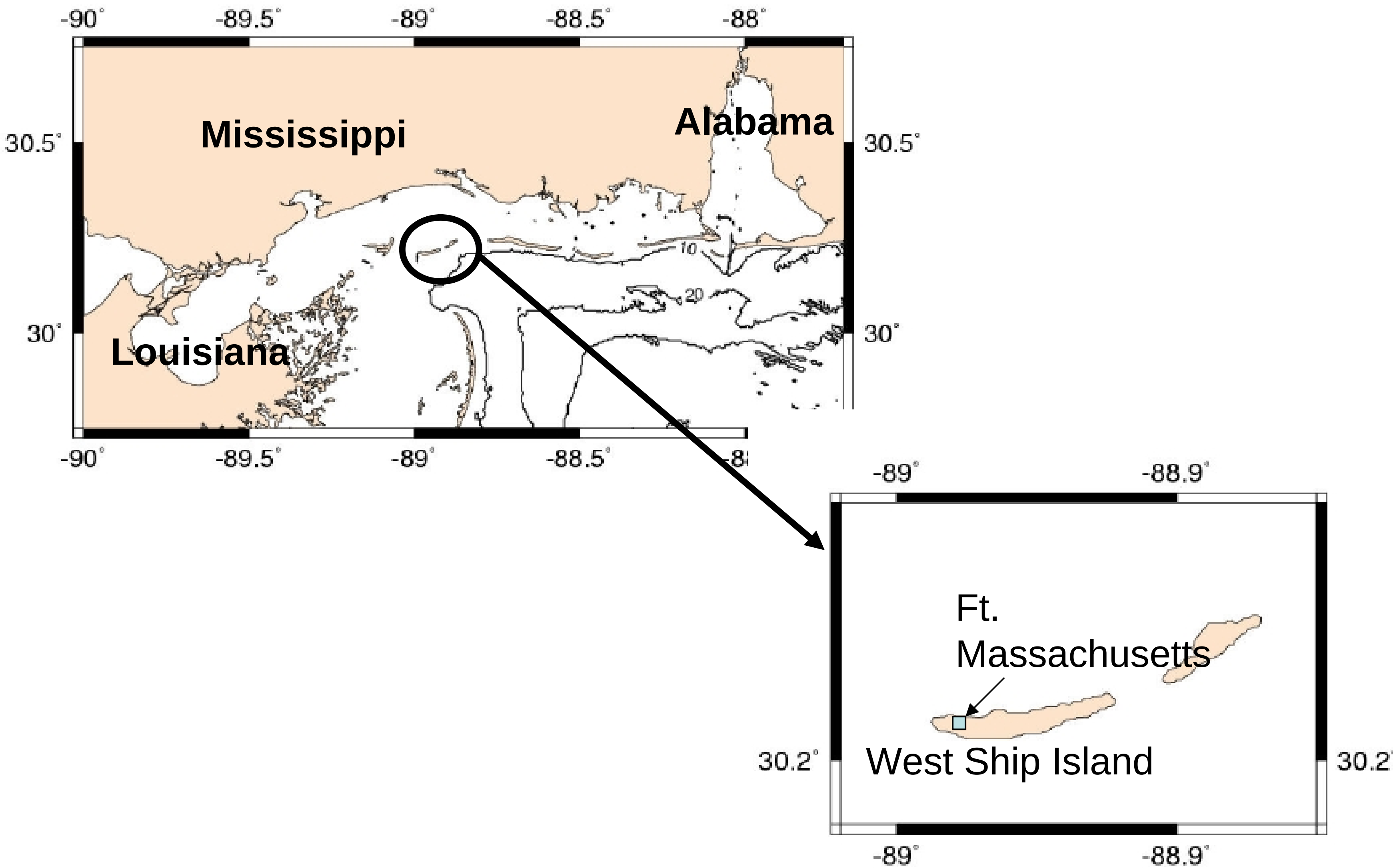
Overall Goal

- Investigate nearshore and sediment dynamics in area of low average wave energy
- Frontal passage – large relative signal
- Gulf of Mexico: site of Northern Gulf Littoral Initiative (NGLI)

Northern Gulf and Ship Island

- Keen et al. (2003) studied erosion patterns on north side of West Ship Island, MS
- Fort Massachusetts may be focal point of sediment erosion during frontal passages – determine effect of nearshore wave driven currents on erosional pattern
- Use location near middle of island as “control”
- Bathymetric profiles were taken (Stone 1998) and blended with NOAA navigation charts

Mississippi Sound and West Ship Island



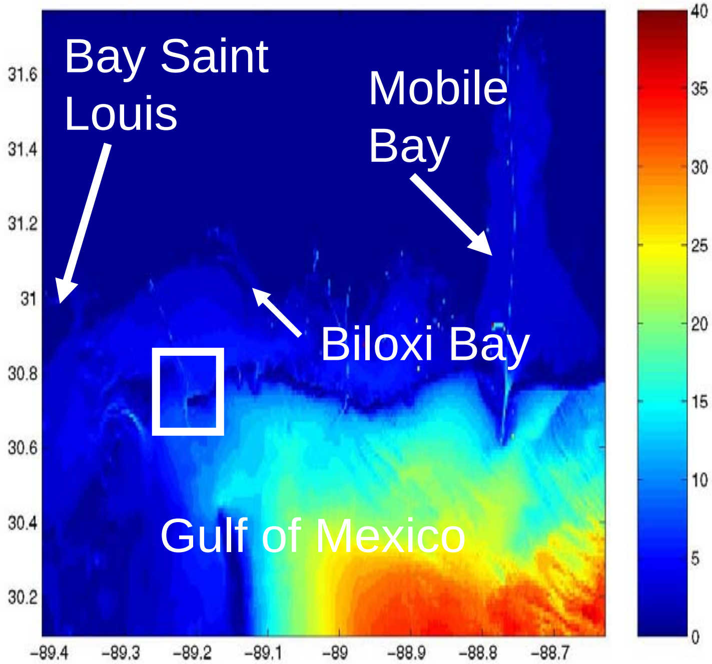
March 19-22 1997

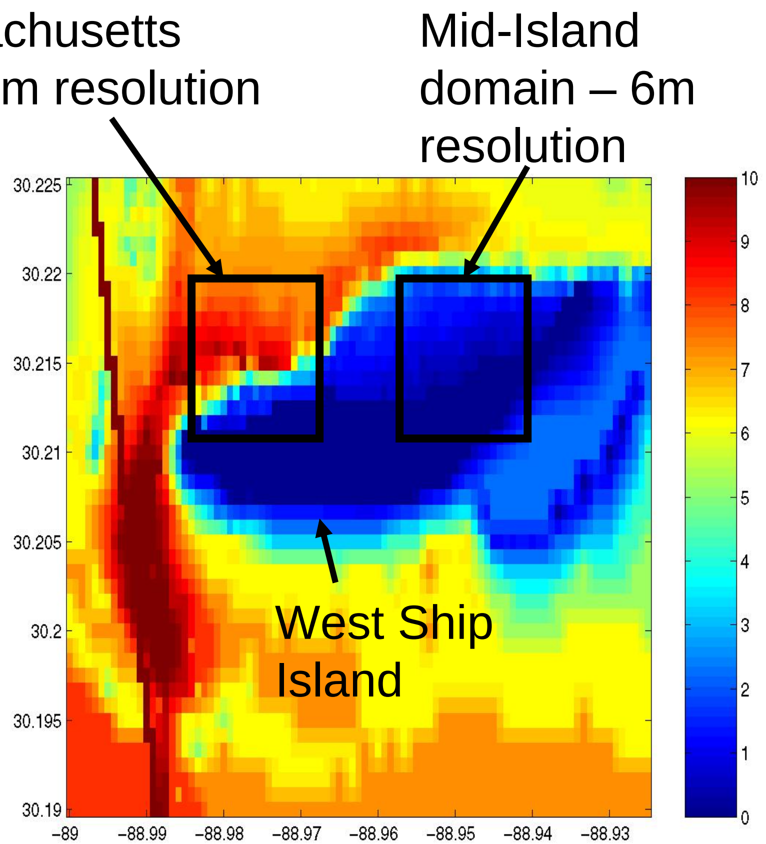
- Passage of cold front
- Area typically low wave energy; conditions during frontal passages emerge as important input for coastal evolution
- Wind, water level and wave data were taken during frontal passage near Ft. Massachusetts – useful for modeling processes at site

SWAN for Mississippi Sound

- Initial wave environment along offshore boundary of domain generated with the wave model SWAN (Booij et al. 1999) applied over Mississippi Sound (0.6 deg. longitude, 0.3 deg. latitude).
- Model forced with winds from measurements near Ft. Massachusetts (Mar 19-22 1997).
- Triple SWAN nest – finest nest forcing nearshore hydrodynamic model

SWAN For Mississippi Sound

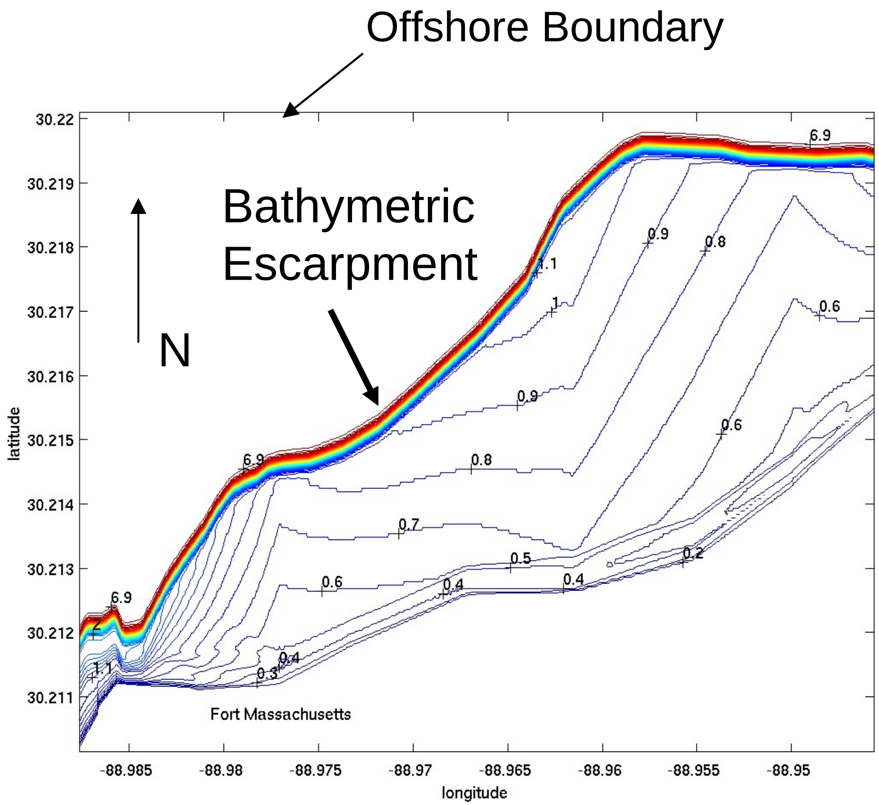




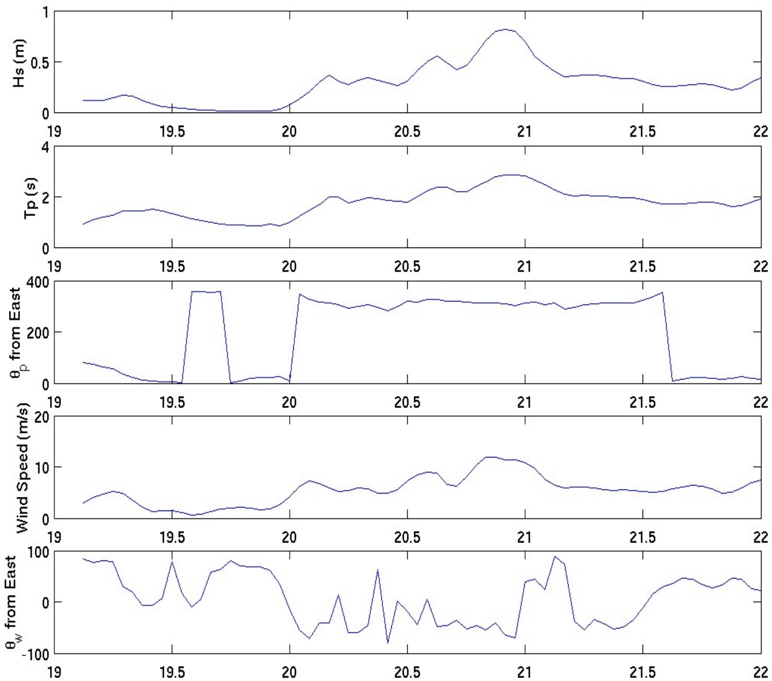
Coarse Grid : 0.005 Deg. Resolution

Fine Grid: 0.00083 Deg. Resolution

Bathymetry and Conditions

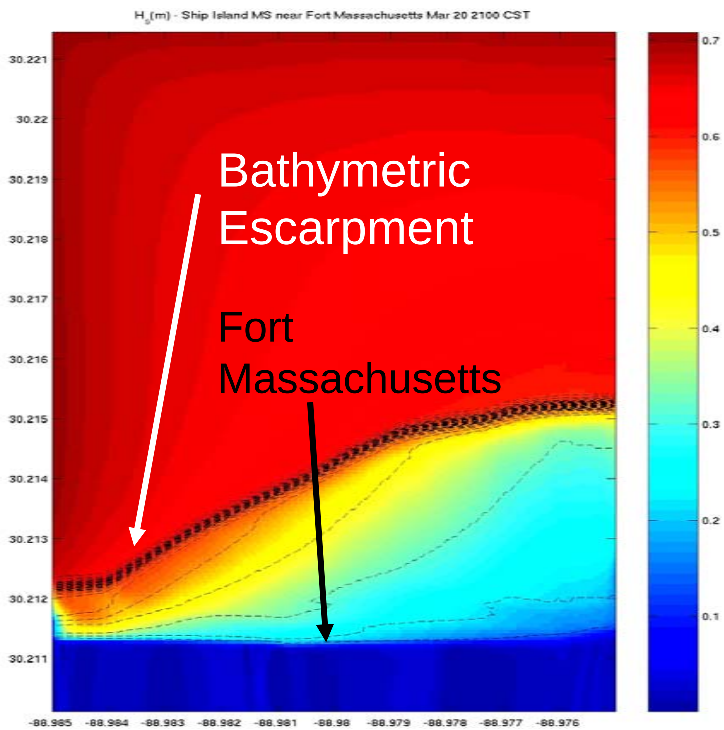


Nearshore bathymetry for West Ship Island – blend of beach profile surveys and navigational charts

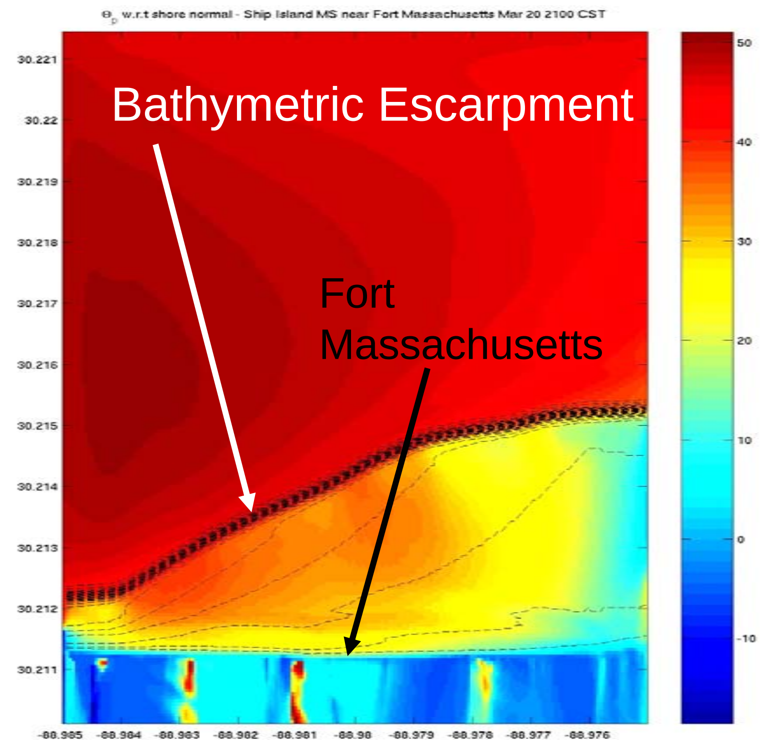


Initial conditions from Sound-wide SWAN

SWAN in Nearshore Areas at Frontal Peak – Ft. Massachusetts



Significant Waveheights (m)

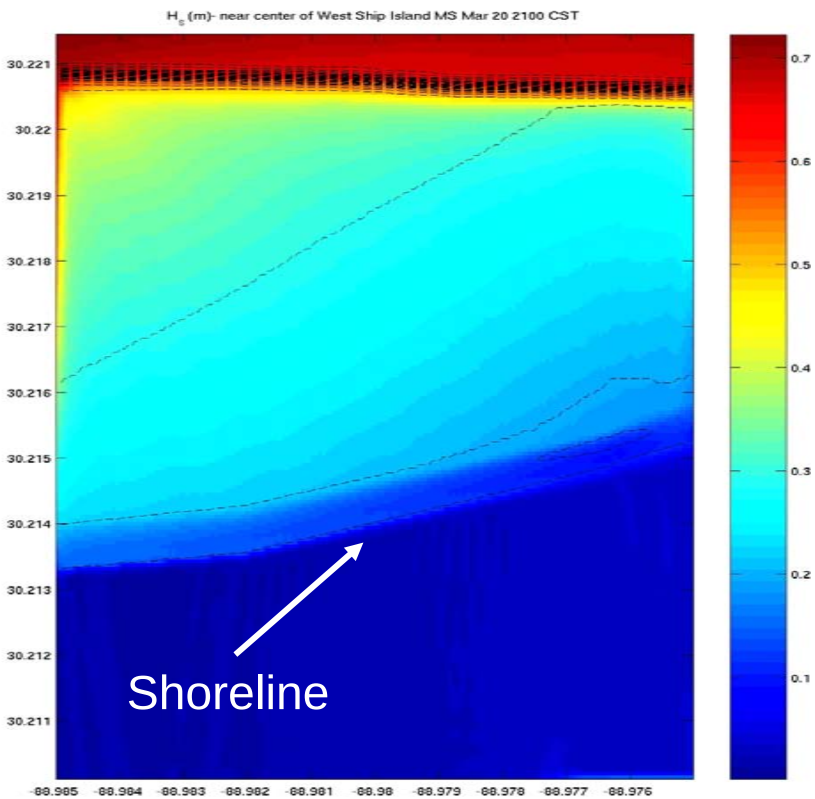


Peak Wave Direction with respect to Shore Normal (deg.)

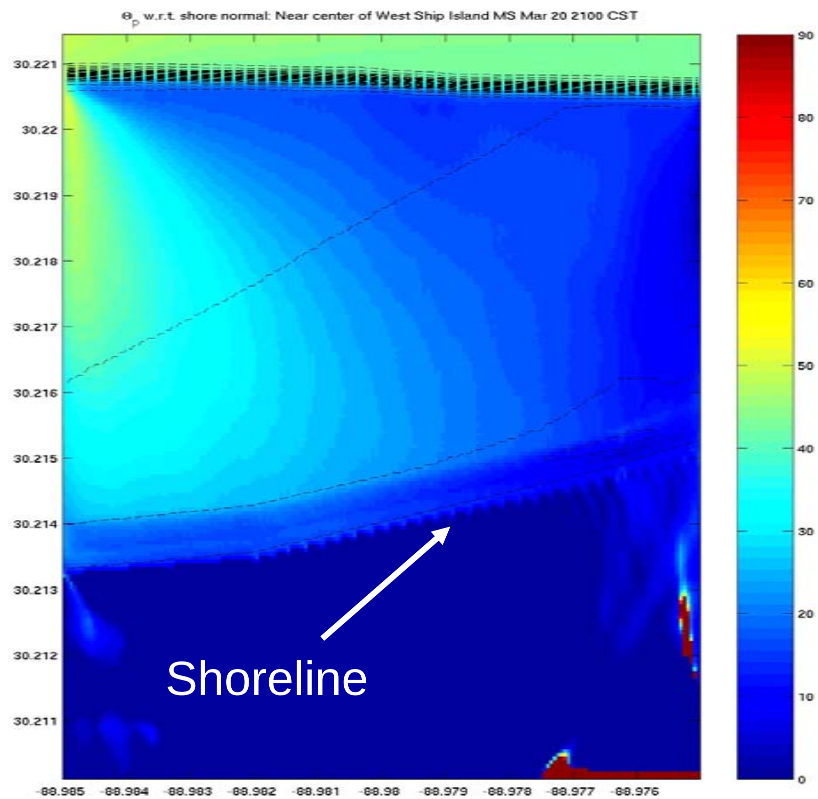
(Positive Angles Toward Right)

Considerable Energy Loss and Sudden Wave Refraction over Bathymetric Escarpment

SWAN in Nearshore Areas at Frontal Peak – Middle of Island



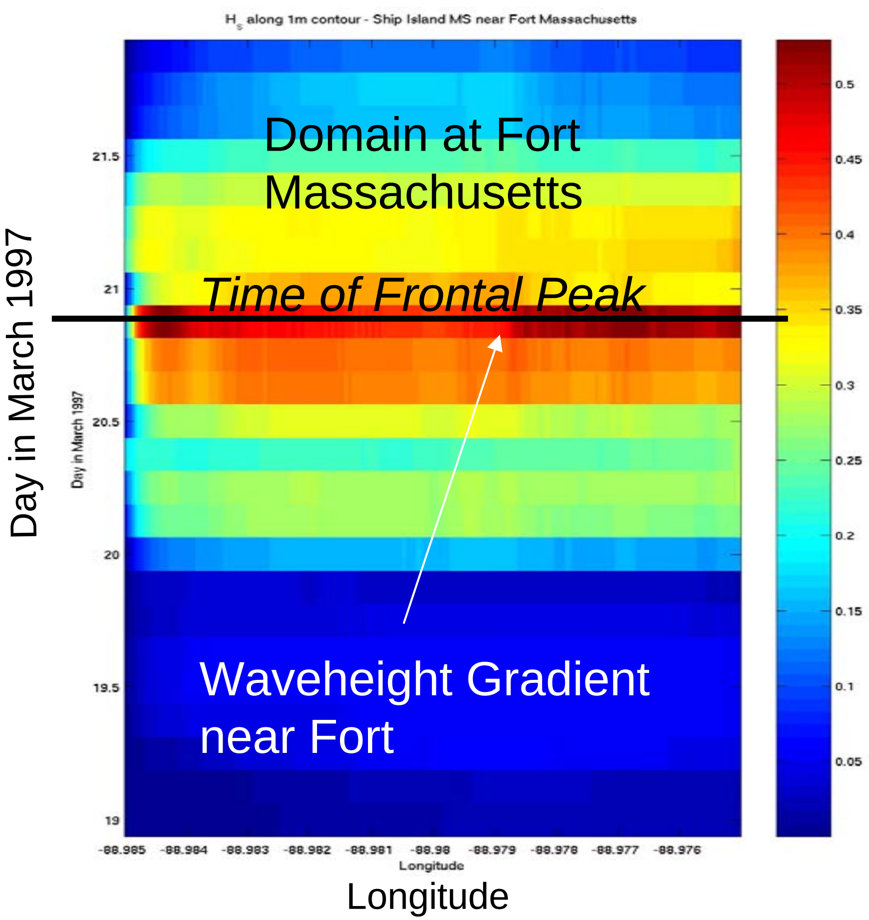
Significant Waveheights (m)

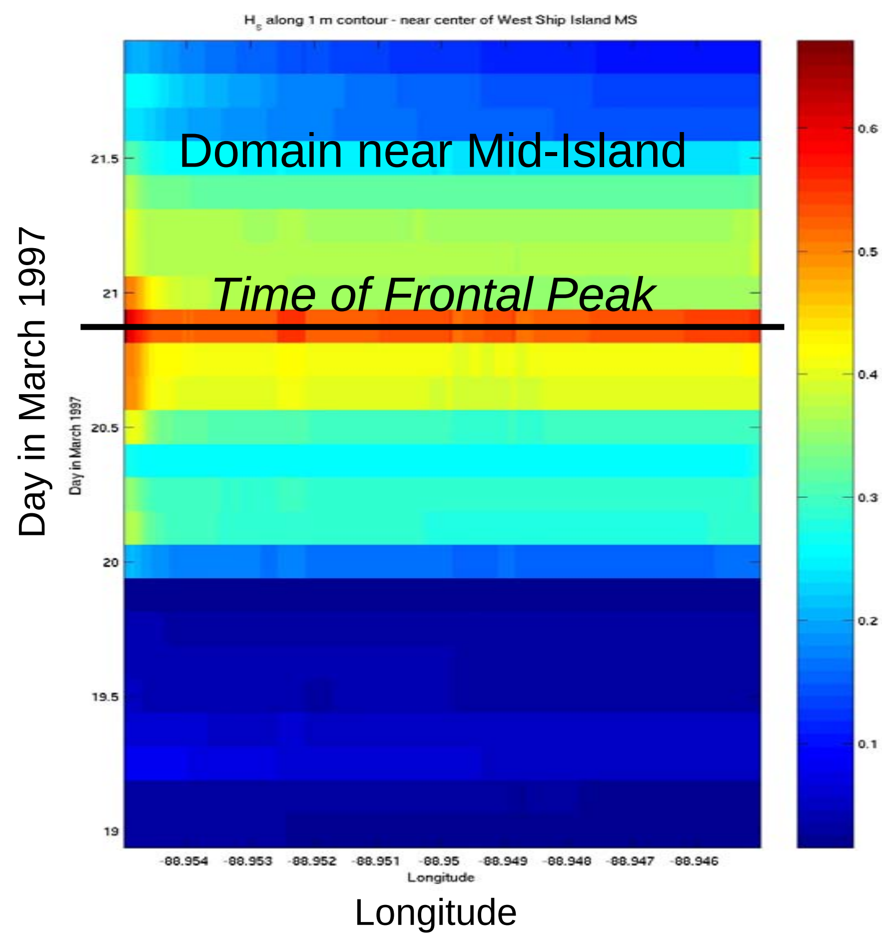


Peak Wave Direction with respect to shore normal (deg.)
(Positive Angles Toward Right)

Longer shelf – More gradual refraction and more uniform wave directions

Evolution of Wave Conditions Along 1 Meter Depth Contour



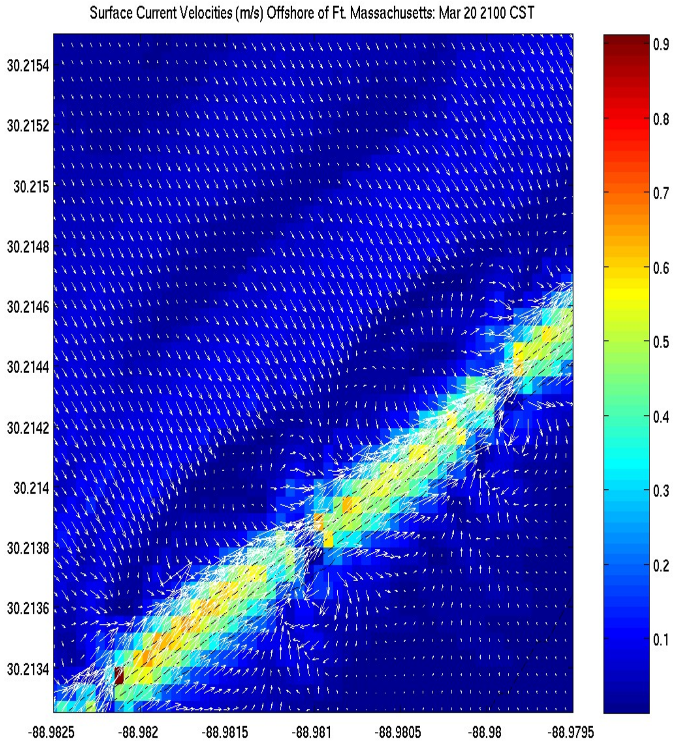


Lack of Waveheight Gradient at Mid-Island During Frontal Peak – Likely Very Weak Currents

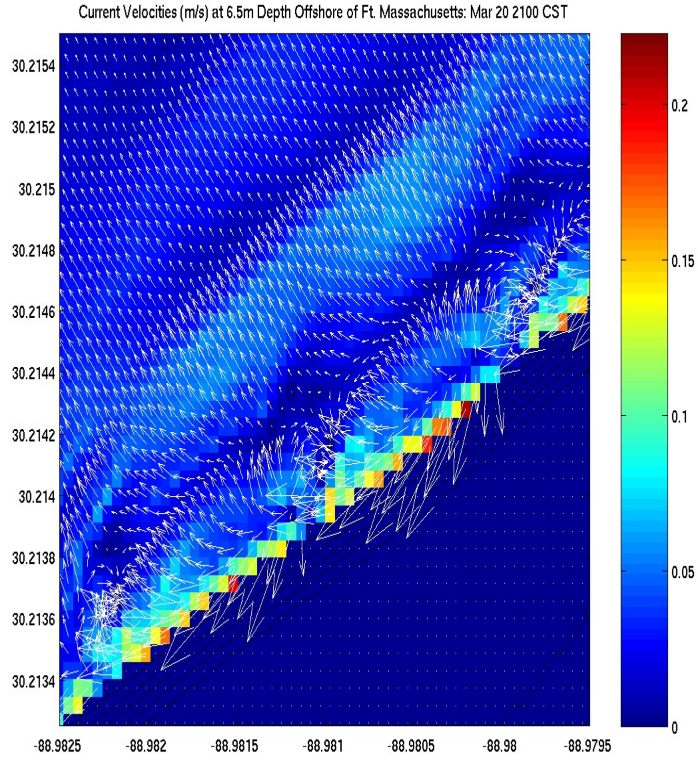
SHORECIRC

- Quasi-3D wave-forced hydrodynamic model (Van Dongeren and Svendsen 2000), extended to random waves (Kaihatu et al. 2002).
- Forced by radiation stress gradients, wave volume fluxes, and wave dissipation
- SWAN modified to provide necessary quantities
- Frontal peak conditions (March 20 1997 21:00 CST) run for peak hydrodynamic conditions.
- Concentrate on Ft. Massachusetts domain; relatively weak currents expected near middle of island

SHORECIRC offshore of Ft. Massachusetts



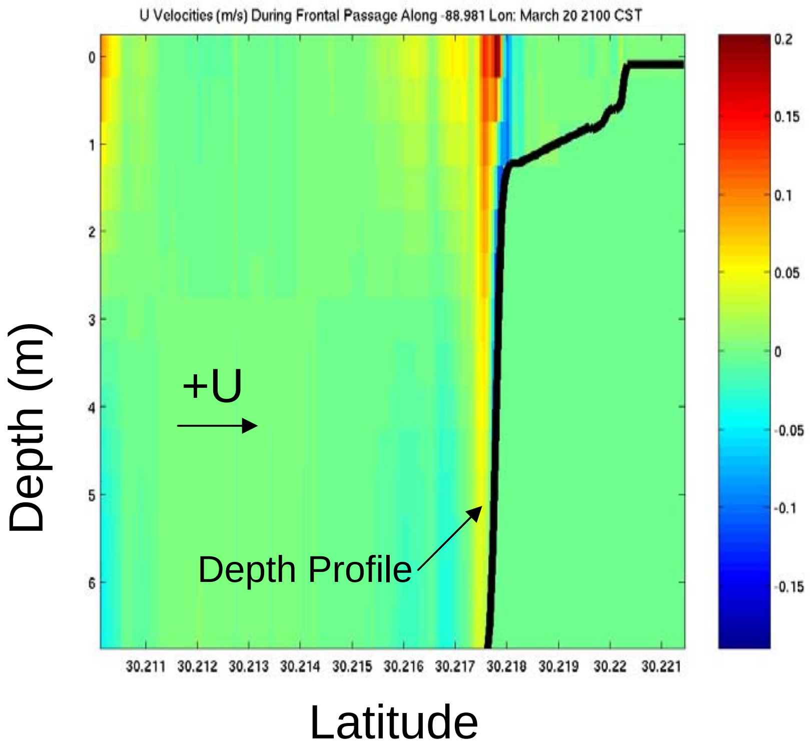
Surface Currents offshore of Fort near escarpment during frontal peak

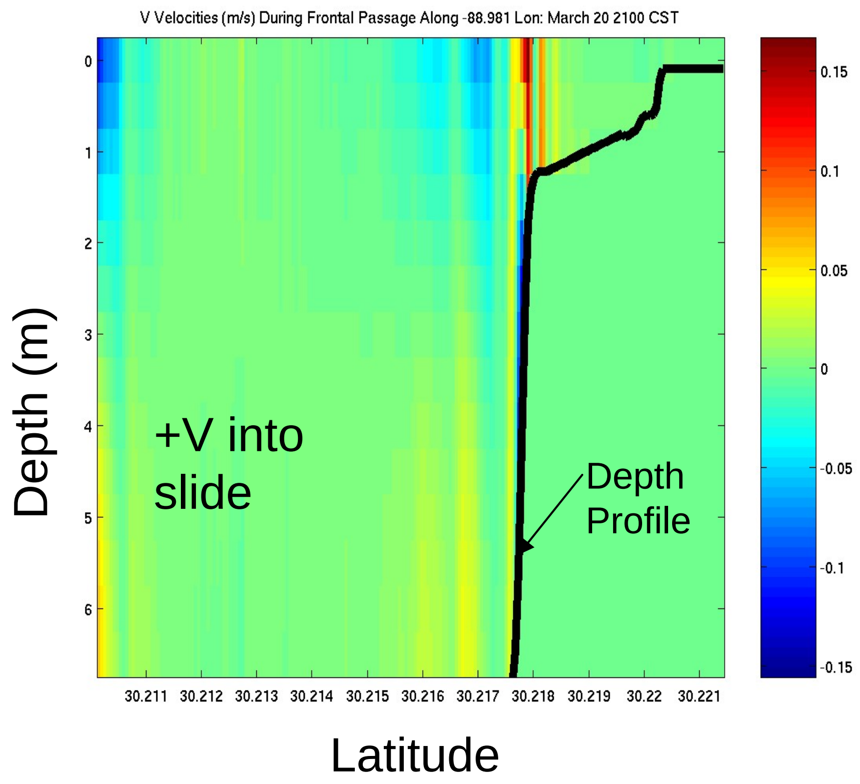


Bottom Currents offshore of Fort near escarpment during frontal peak

Currents exhibit strong interaction with escarpment – might block potentially high wave-driven bottom currents from shoreline

Depth-Varying Currents along –88.981 Longitude





Near-bottom currents effectively blocked from shoreline by bathymetric escarpment – strong shear over depth change

HydroQual Contaminant Model (HQCM)

- Extracted from the ECOMSED model
- Calculates entrainment and transport of both cohesive and noncohesive fractions
- Tracks bed thickness and properties
- Updated input and output
- Fully 3D computations

HQCM Formulation

- Bed sediment is split between mud and sand (> 64 microns)
- Entrainment is dependent on sand characteristics:
  - Bed shear velocity ($\rho_s \tau_b$) exceeds sand critical shear stress
  - Bed shear velocity exceeds sand settling velocity
- Van Rijn's transport equation is solved for total suspended transport load, divided between components
- Approximate suspended load:

$$q_S = F\overline{u}dc_a$$

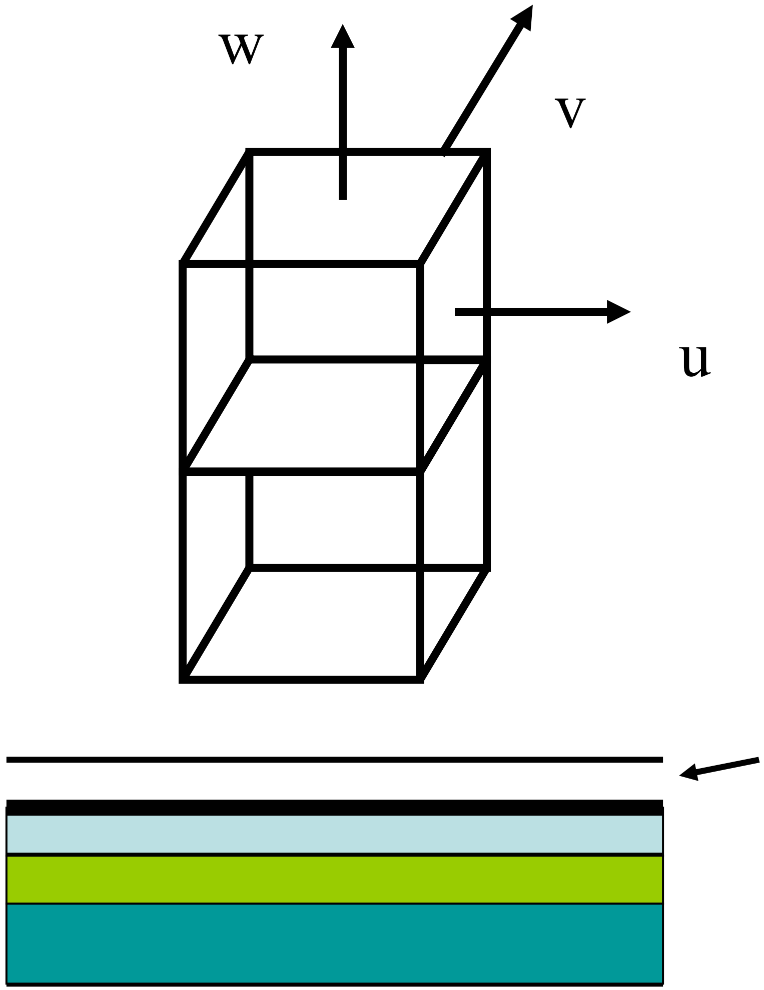
F is representation of more complex solution of transport equation.

$$F = \frac{\left[\frac{a}{d}\right]^{Z'} - \left[\frac{a}{d}\right]^{1.2}}{\left[1-\frac{a}{d}\right]^{Z'}\left[1.2 - Z'\right]}$$

- $0.3 \le Z' \le 3$ and $0.1 \le a/d \le 1.0$
- $\bar{u}$ = mean flow velocity
- D = flow depth
- C_a = reference concentration

- Suspended sediment load divided based on availability mud and sand in bed.
- Uses active layer concept based on D_{50}
- Tracks bed thickness over time and space using fraction of mud and sand deposited and/or eroded
- Vertical and horizontal mixing use mixing coefficients from hydrodynamic model

3D computation grid for water column and sea bed



Active layer consists of bed load and saltation

Sea Floor consists of mixed sand and mud layers

HQCM Input

- 3D transport fields, $u \cdot dy \cdot dz$, $v \cdot dx \cdot dz$, and $w \cdot dx \cdot dy$
- Horizontal mixing based on flow field
- Vertical mixing based on profile and T/S stratification
- Surface elevation history
- Input using netCDF files
- Presently preparing SHORECIRC output for input to HQCM to simulate wave-induced transport

HQCM Output

- Bed thickness
- 3D sediment distributions in water and bed
- Dissolved constituents (e.g., Oxygen)
- 3D contaminant distribution both within water column and bed, fractionated between mud and sand
- Output in netCDF format

Summary

- Development of a coupled wave-current-sedimentation model underway
- Focus on frontal passage over West Ship Island, MS
- The wave model SWAN provided forcing conditions for the hydrodynamic model SHORECIRC
- Steep bathymetric escarpment dissipates majority of wave energy and blocks/steers bottom current
- Strong shear over escarpment may affect sedimentation
- Efforts to couple wave-driven hydrodynamics to HQCM now underway to test hypothesis and validate results

Acknowledgments

Funding for this work was provided by the Office of Naval Research through the Naval Research Laboratory, Program Element 62435N.

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